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PCT/EP 05 / 05154

INVESTOR IN PEOPLE

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Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

25 MAY 2004

1. Your reference	2004P08677 GB / / CF / GD
2. Patent application number *(The Patent Office will fill in this part)*	0411607.5
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	Oxford Magnet Technology Ltd. Wharf Road, Eynsham, Witney OX29 4BP
Patents ADP number *(if you know it)*	00647776003
If the applicant is a corporate body, give the country/state of its incorporation	UNITED KINGDOM
4. Title of the invention	RECONDENSER INTERFACE
5. Name of your agent *(if you have one)*	
"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Siemens plc Intellectual Property Department The Lodge, Roke Manor Romsey, Hampshire SO51 0ZN
Patents ADP number *(if you know it)*	04095873005

6. Priority: Complete this section if you are declaring priority from one or more earlier patent applications, filed in the last 12 months.	Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. Divisionals, etc: Complete this section only if this application is a divisional application or resulted from an entitlement dispute *(see note f)*.	
8. Is a Patents Form 7/77 (Statement of inventorship and of right to grant of a patent) required in support of this request? Answer YES if: *a) any applicant named in part 3 is not an inventor, or*	Yes

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b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
Otherwise, answer NO (see note d).

9. Accompanying documents: A patent application must include a description of the invention. Not counting duplicates, please enter the number of pages of each item accompanying this form.

Continuation sheets of this form	
Description	4
Claim*(s)*	0
Abstract	0
Drawing*(s)*	2

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translation of priority documents	
Statement of inventorship and right to grant a patent *(Patents Form 7/77)*	1
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	1 Letter
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application

Signature

Clive French
Chartered Patent Agent

Date
21.05.2004

12. Name and daytime telephone number of Person to contact in the United Kingdom

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Recondenser Interface.

Synopsis.

MRI magnet systems use refrigerators to reduce the heat load onto the cryogen vessel in order to reduce or eliminate the consumption of cryogenic liquid [commonly liquid helium]. The refrigerator must make good thermal contact to the objects to be cooled whilst being easy to remove and replace for servicing.

A means is described which uses two recondensing processes to achieve good thermal contact, eases removal and replacement of the refrigerator for servicing, and eliminates the possibility of air entering the cryogen vessel during refrigerator servicing.

Recondenser Interface.

Background.

MRI magnet systems are used for medical diagnosis. A requirement of an MRI magnet is a stable, homogeneous, magnetic field. In order to achieve stability it is common to use a superconducting magnet system which operates at very low temperature, the temperature being maintained by cooling the superconductor, typically by immersion, with a low temperature cryogenic fluid, such as, but not restricted to, liquid helium, liquid neon, liquid hydrogen, and liquid nitrogen. Cryogenic fluids are expensive fluids, and it is desirable that the magnet system should be designed and operated in a manner to reduce to a minimum the amount of cryogenic liquid used.

The superconducting magnet system typically comprises a set of superconductor windings for producing a magnetic field, a cryogenic fluid vessel which contains the superconductor windings, one or more thermal shields completely surrounding the cryogenic fluid vessel, and a vacuum jacket completely enclosing the one or more thermal shields. It is common practice to use a refrigerator to cool the thermal shields to a low temperature in order to reduce the heat load onto the cryogen vessel. It is also known to use a refrigerator to directly refrigerate the cryogen vessel, thereby reducing the cryogen fluid consumption to zero. In both cases it is necessary to achieve good thermal contact between the refrigerator and the object to be cooled. Achieving good thermal contact at low temperature is difficult, and whilst adequate thermal contact can be achieved using pressed contacts at the thermal shield temperatures [note that the refrigerator needs to be removable and replaceable for servicing, so the thermal contacts need to be removable] it becomes more difficult to achieve the desired thermal contact at very low temperature.

Condensation provides a good means of thermal contact so it is preferable, if cryogen vessel refrigeration is needed, to situate the vessel cooling part of the refrigerator within the cryogen gas. This means that the refrigerator is surrounded by the cryogen gas.

The refrigerator is subject to wear, and must be replaced after a certain time in order to maintain adequate performance. It is therefore placed in a means of removably interfacing it to the magnet system.

Problem.

At cryogen recondensing temperature, provide adequate thermal contact between a cryogenic gas to be cooled and a refrigerator used for cooling whilst maintaining ease of removal of the refrigerator for servicing and eliminating the possibility of air entering the cryogen vessel.

Solution.

Condensation is a good means of transferring heat to a cooler surface. Use the condensation process twice so that the refrigerator can be isolated from the gas and liquid cryogen used to cool the superconductor magnet.

Detailed description.

Figure 1 shows a schematic of an MRI magnet system fitted with a refrigerator interface as described in patent application TBD [side sock refrigerator interface]. Liquid cryogen vessel [1], containing superconductor magnet [not shown] is completely surrounded by one or more thermal shields [2], which are in turn completely surrounded by a vacuum jacket [3]. Removably fitted to the magnet system is refrigerator [4] thermally interfaced by interface sock [5] so as to cool the thermal shields and recondense cryogen gas and deliver it back to the cryogen vessel [1] by tube [6].

Figure 2 shows the refrigerator interface in more detail. The second stage [7] of the refrigerator [4] is situated in the lower part [8] of refrigerator interface sock [5]. Second stage [7] terminates in cooling stage [9] which provides cooling power to the object to be cooled. Cooling stage [9] is preferably finned so as to improve recondensation heat transfer. The bottom of interface sock [8] is terminated in a leak tight manner with thermally conducting base [10] which isolates it from the cryogen fluid in cryogen vessel [1]. Base [10] is connected in a leak tight manner to chamber [11] from which pipe [6] communicates for fluid flow to and from cryogen vessel [1].

Liquid cryogen [12] partly fills the bottom of interface sock [8] and provides heat transfer medium for transferring heat from plate [10] to second stage recondenser [9] by recondensation at [9] and boiling at [10]. The upper surface of cryogen liquid [12] should not touch the recondenser stage [9] since this would reduce the area available for recondensation, and therefore the rate of heat transfer. Base [10] is made from highly thermally conducting material, typically copper, and provides good thermal conduction from its upper surface in contact with liquid [12] to its lower surface within chamber [11].

The upper surface of base [10] may be finned or otherwise machined or prepared so as to increase the area for heat transfer by boiling, but the preparation of the surface should be such as to allow free flow of liquid across the full face of base [10].

The first stage thermal contact between the refrigerator and the sock has gas paths [13] so that gas can pass between the upper and lower parts of the interface sock for evacuation of the sock, refilling with cryogen gas, and release of cryogen gas.

In operation, after servicing the refrigerator, when the magnet system is cold, but the refrigerator is still hot, air is evacuated from the interface sock through port [14] and the sock filled with clean cryogen gas. This may be repeated a number of times to ensure purity of the gas remaining in the interface sock. The refrigerator is then started and allowed to cool to its operating temperature. When the refrigerator is fully cold, or during the cooling, a quantity of cryogen gas is slowly admitted through port [14] into the sock. The gas is admitted slowly so that the refrigerator can cool it as

appropriate and liquefy some in the bottom of the sock. The quantity of gas admitted is measured so that the appropriate quantity of liquid [12] is condensed in the bottom of the sock.

On first putting in the refrigerator, with both the refrigerator and the magnet system hot, air is evacuated from the interface sock through port [14] and the sock filled with clean cryogen gas. This may be repeated a number of times to ensure purity of the gas remaining in the interface sock. During cooling of the magnet system and the refrigerator to operating temperature, or when the magnet system and refrigerator have been cooled to operating temperature, cryogen gas is slowly admitted through port [14] into the sock. The gas is admitted slowly so that the refrigerator can cool it as appropriate and liquefy some in the bottom of the sock. The quantity of gas admitted is measured so that the appropriate quantity of liquid [12] is condensed in the bottom of the sock.

When the refrigerator is turned off for servicing, or if the refrigerator should be turned off or stopped unintentionally, the liquid cryogen [12] will evaporate. A pressure relief valve [15] is fitted to the interface sock to prevent excessive pressure developing in the sock. Alternatively, since the quantity of liquid cryogen [12] is small, it could be allowed to boil off into a reservoir and then recondensed when the refrigerator restarted. A volume of about 2 litres pressurized to about 2 bar would be sufficient to provide adequate gas for recondensing heat transfer liquid [12].

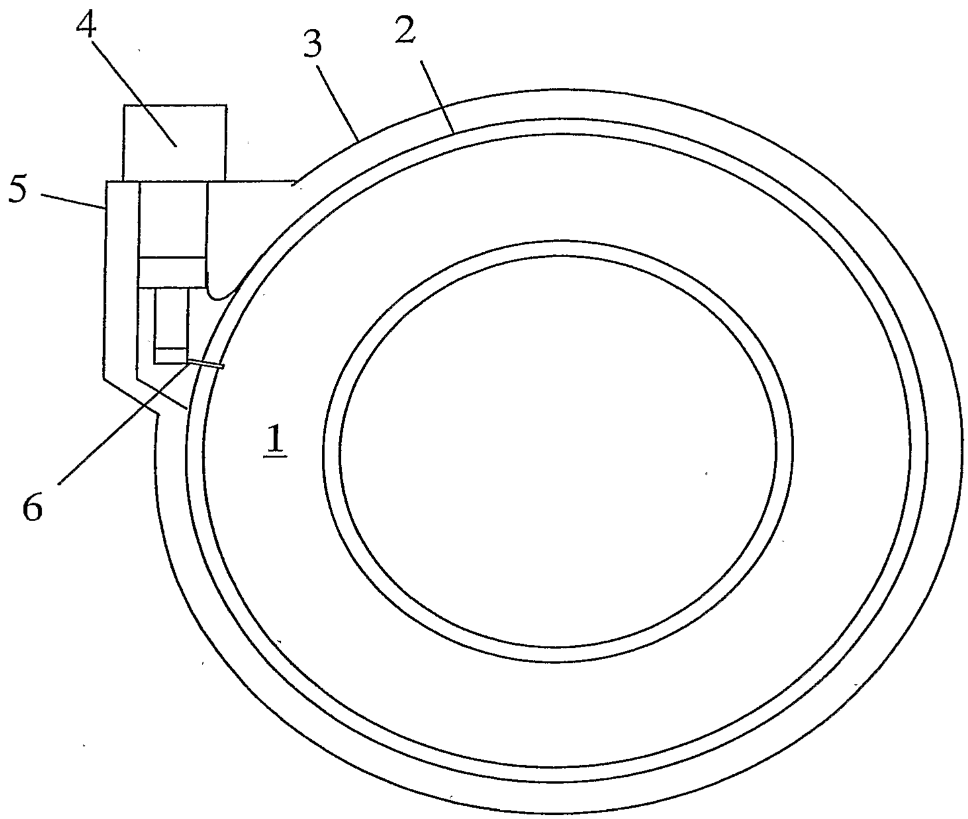

Figure 1.

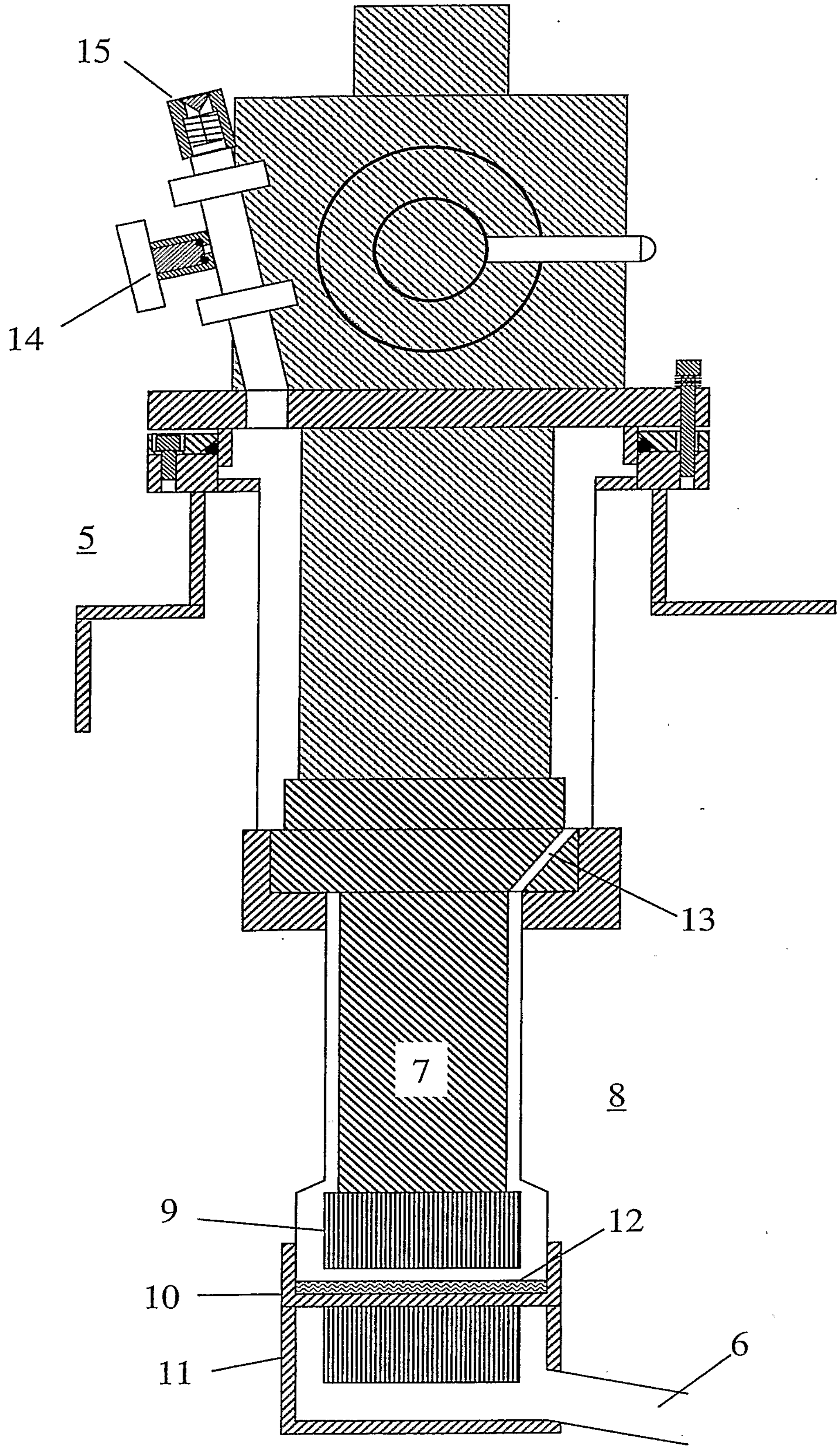

Figure 2.